IMPACTS OF CLIMATE CHANGE ON RESIDENTIAL ELECTRICTY CONSUMPTION: EVIDENCE FROM BILLING DATA

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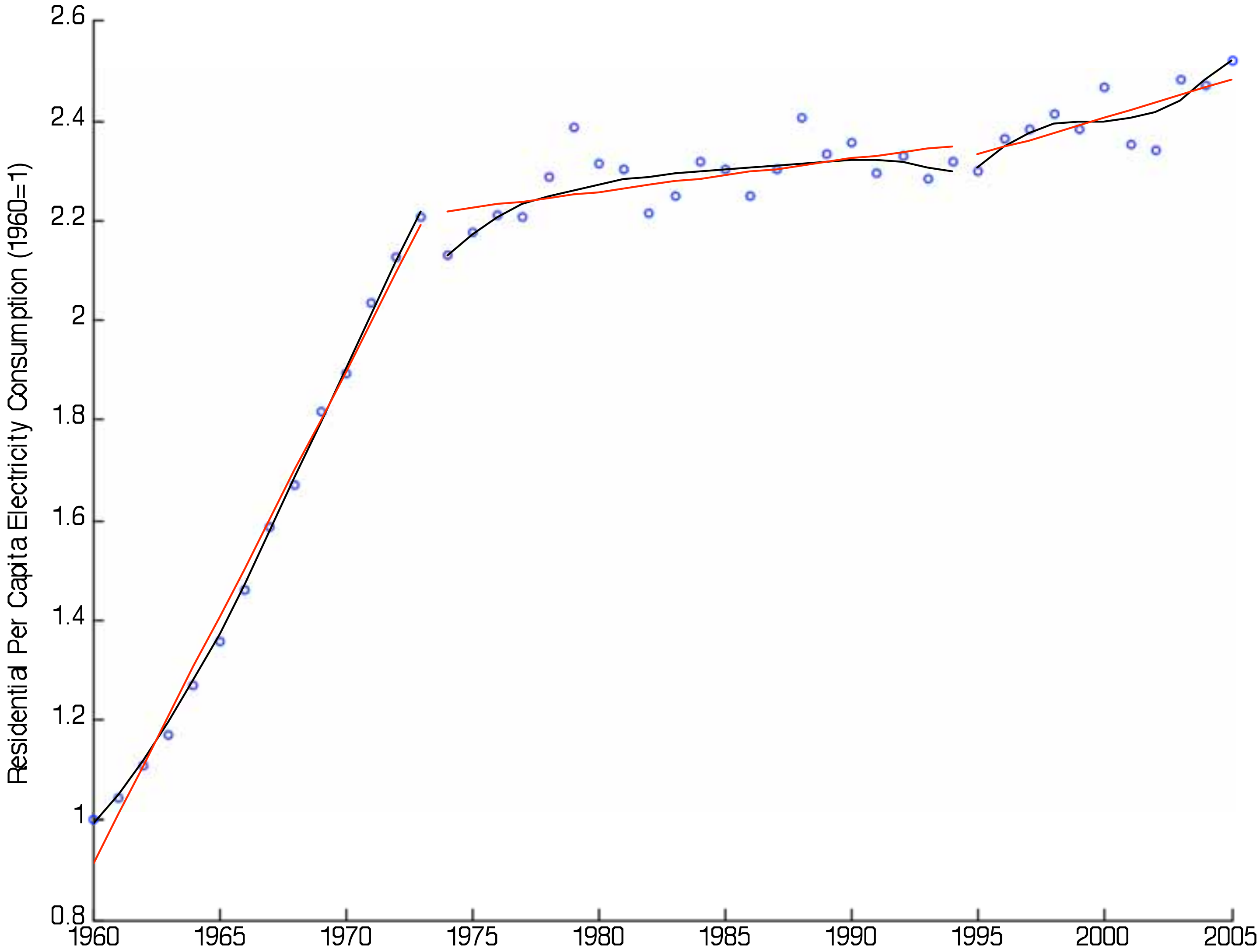
California's Residential Sector Electricity Consumption

- More than quadrupled since 1960
- Share in total consumption increased from 26% to 34%.
- Consumption equivalent to total consumption of Finland, Argentina or half of Mexico
- Provided by three major investor owned utilities (SCE, SDG&E, PG&E) and over 100 municipal utilities.

California Per Capita Electricity Consumption



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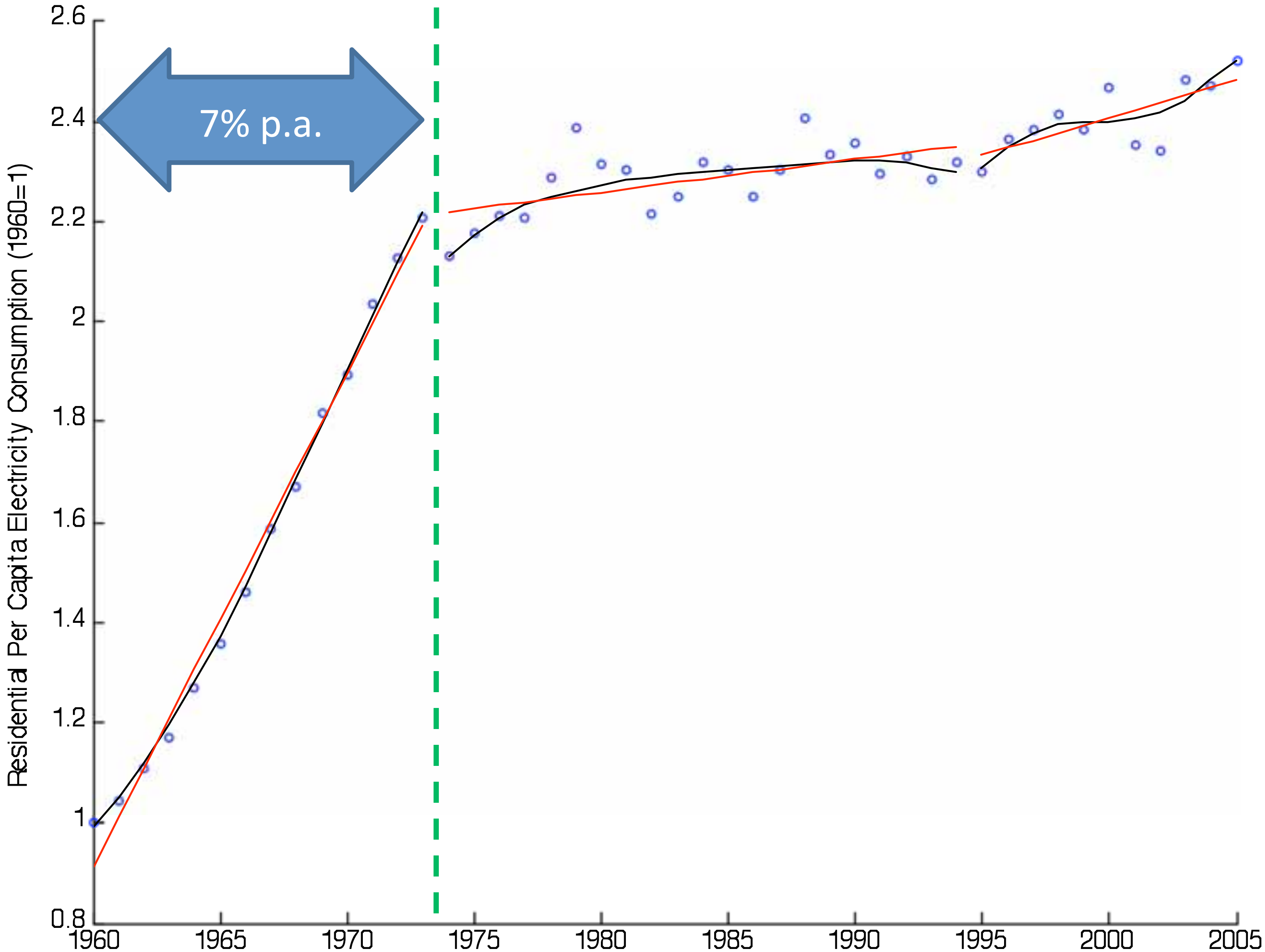

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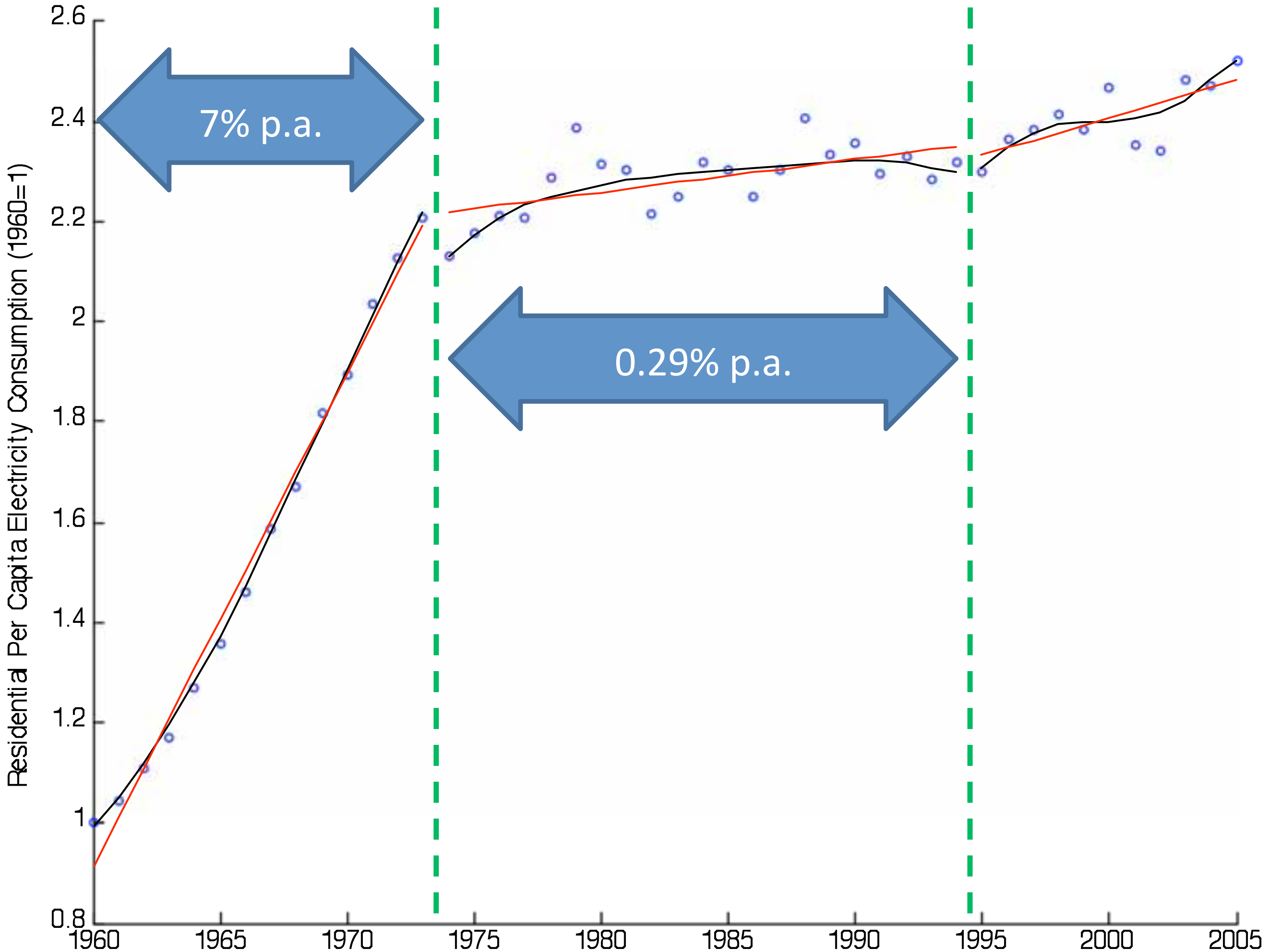

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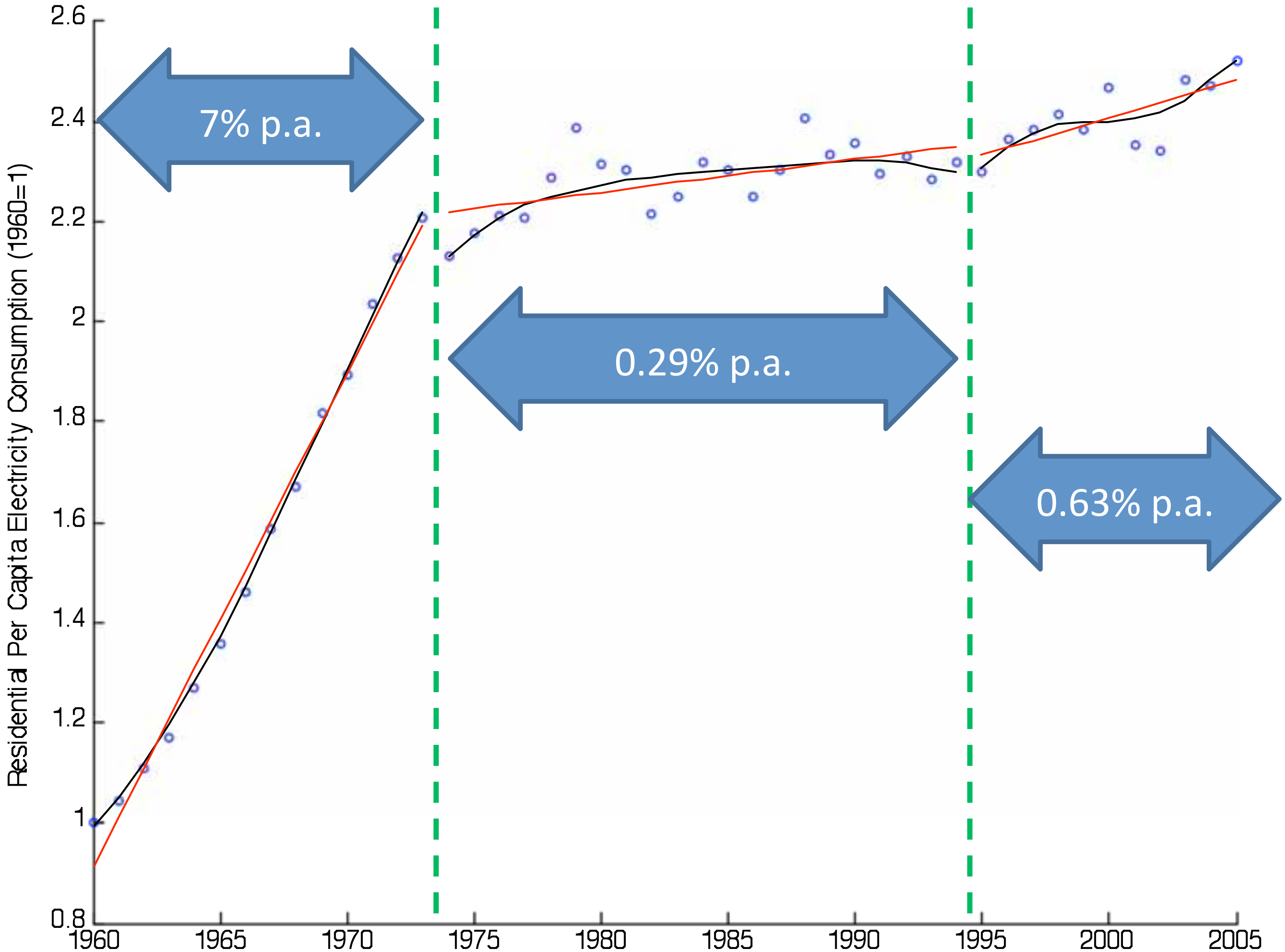


Impacts of Climate Change on Electricity Consumption

- Bottom-Up Simulation Models
  - EPA (1989) : 1.8^{o}F-2.5^{o}F increases in 2010 → 9%-19% increase in electricity consumption
  - Baxter & Calandri (1992): 1.1^{o}F-3.4^{o}F increases in 2010 → 0.6%-2.6% increase in electricity consumption
- Econometric Based Simulation Models
  - Mendelsohn (2003)
  - Franco and Sanstad (2008) : 0.9%-20% increases by 2099
  - Deschênes and Greenstone (2007) :15%-30% increases by 2099

Our Approach

- Use random fluctuations in weather to estimate temperature response of residential electricity consumption.
- Use flexible functional form of temperature response.
- Allow for geographically differentiated temperature response
- Simulate future household and aggregate demand under different climate, price and population scenarios

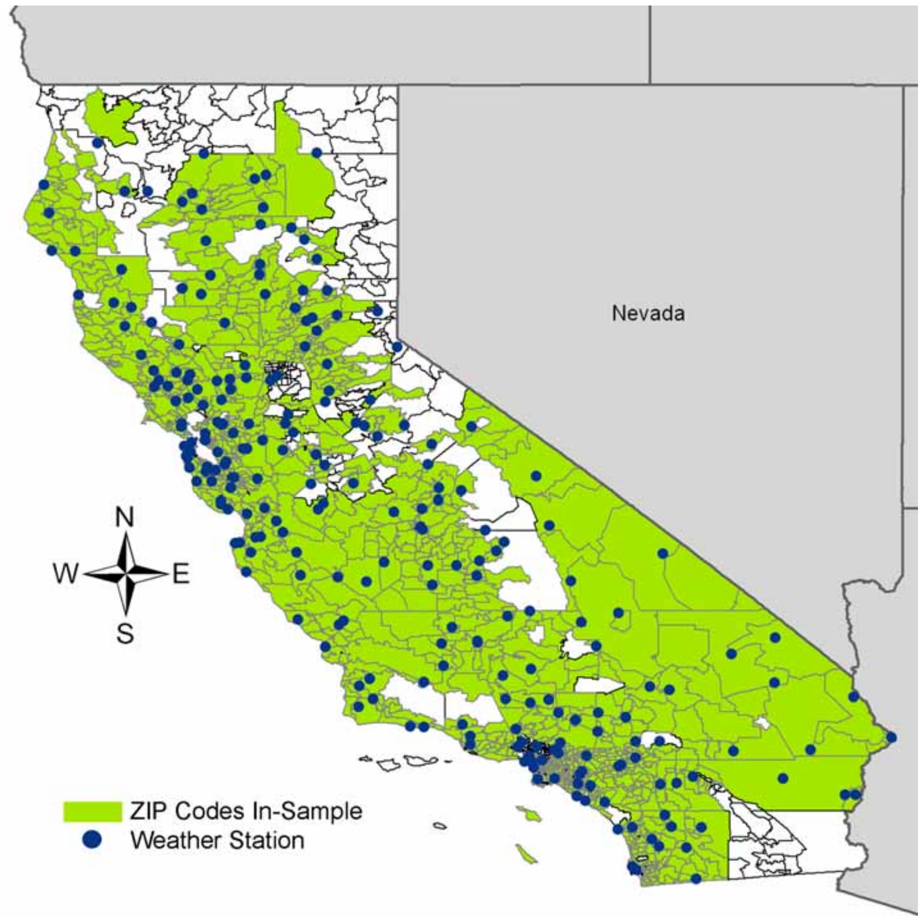
Billing Data

- Complete residential billing data for California's investor owned utilities (thanks to UCEI/CSEM).
- ~80% of all California households from 2003-2006
- Separate out CARE households
- Limit to households with 25-35 day billing cycle
- Drop bills with daily consumption less than 2 Kwh and more than 80 Kwh
- Randomly sample data by zip code

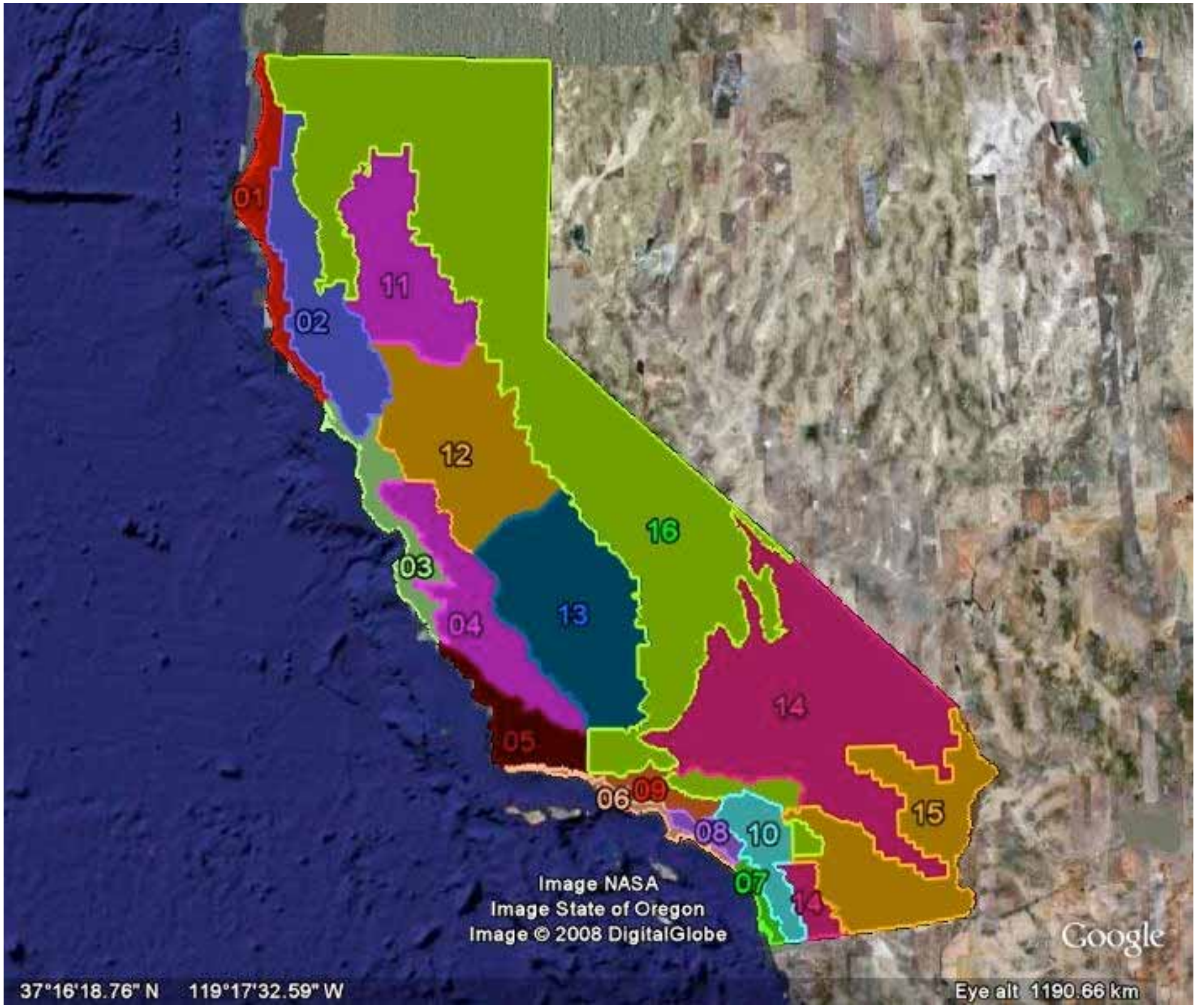
Data : Weather data

- Daily mean temperature and precipitation data from 269 weather stations.
  - Drop stations at elevations more than 7,000 feet.
  - Drop stations reporting fewer than 300 days in any single year.
  - Filling missing value using information from 10 closest stations.

Data Coverage

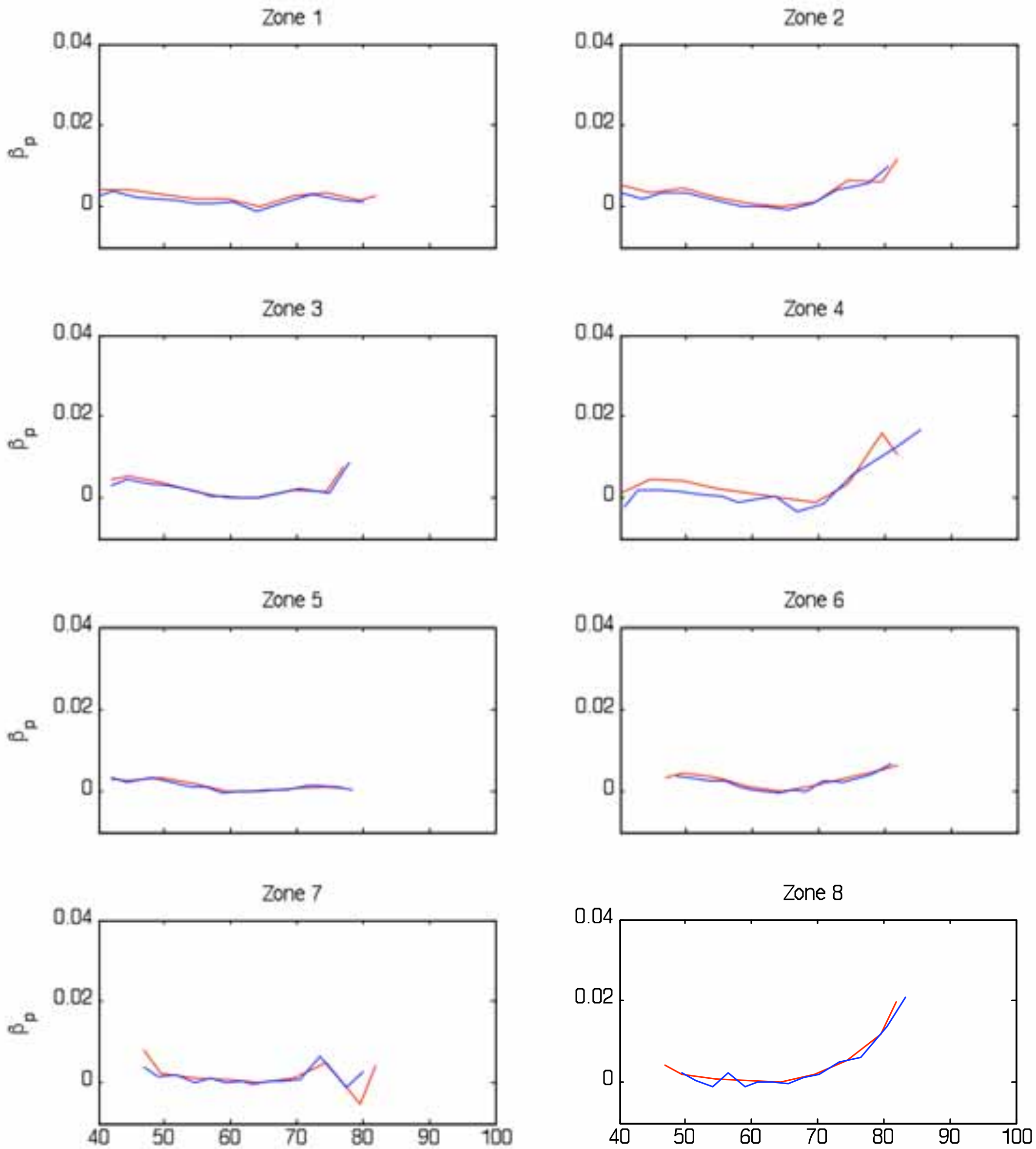


California Building Climate Zones



Estimated climate response functions:

percentile bins (blue), equidistant bin(red)



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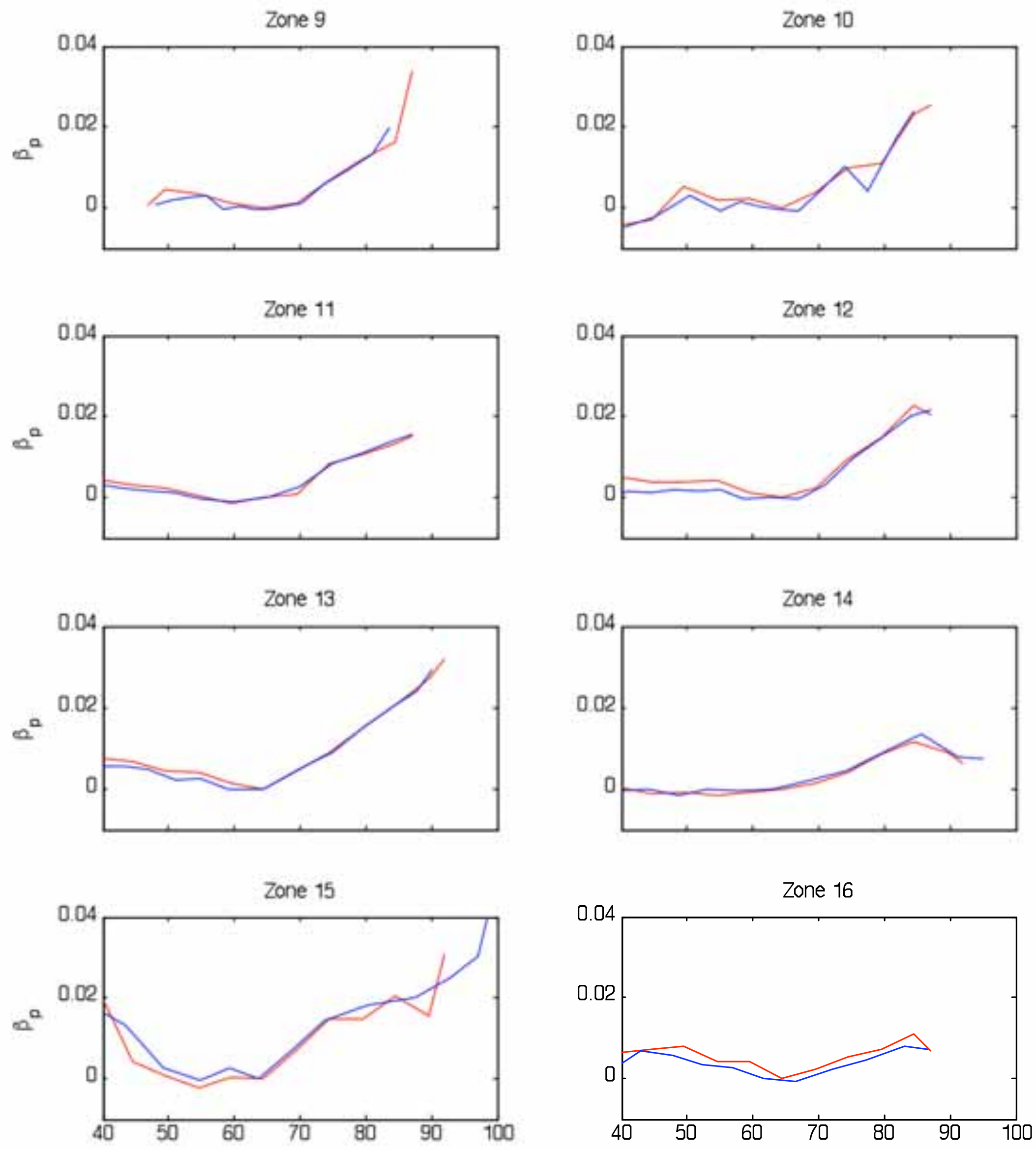
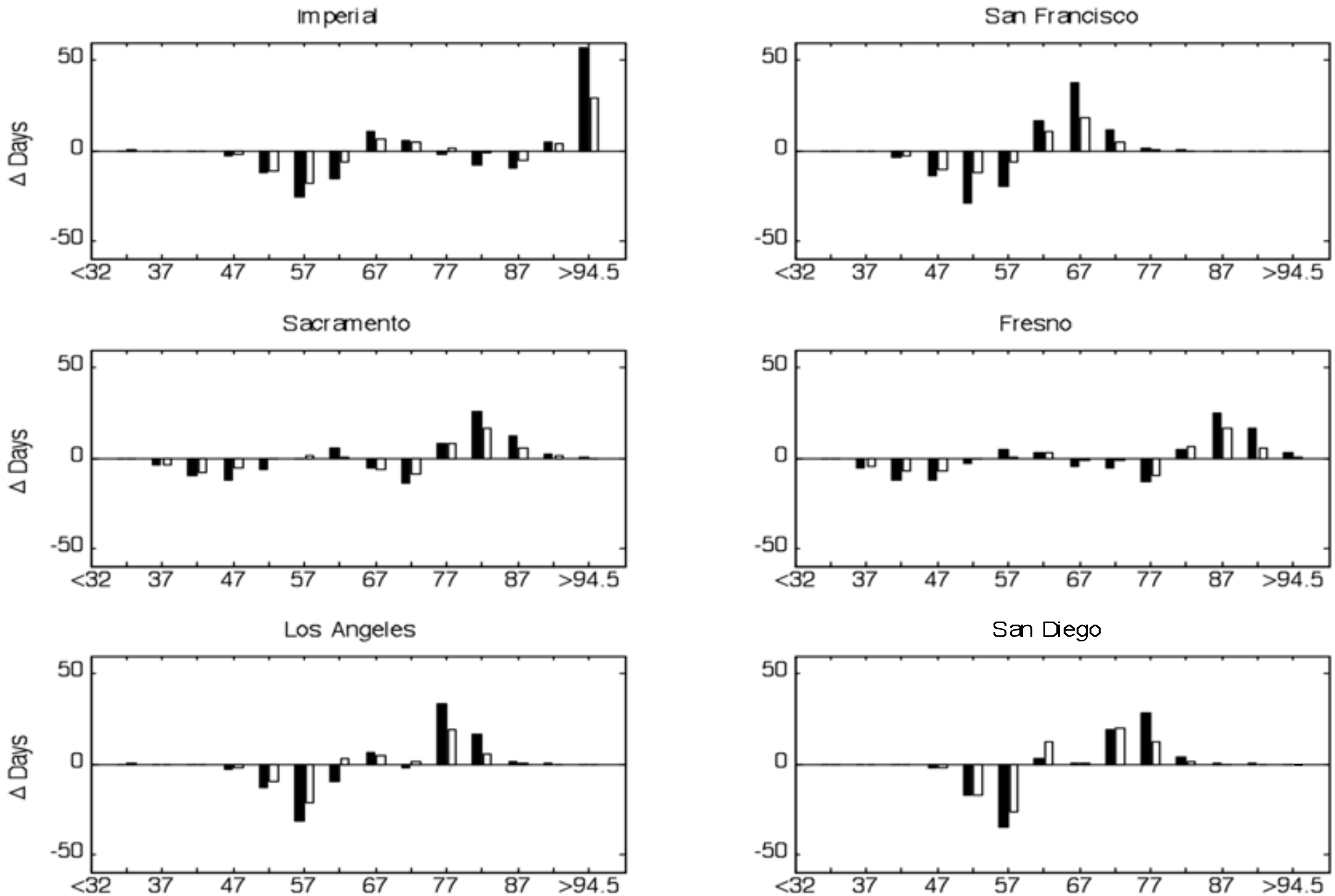


Projected temperature data

- National Center for Atmospheric Research Parallel Climate Model (NCAR) scenarios A2 and B1 ➡
- The model were provided in their downscaled version
  - Bias correction and spatial downscaling (BCSD) (Maurer and Hidalgo, 2008)
  - Constructed Analogues algorithms (CA) (Hidalgo et.al, 2008) ➡

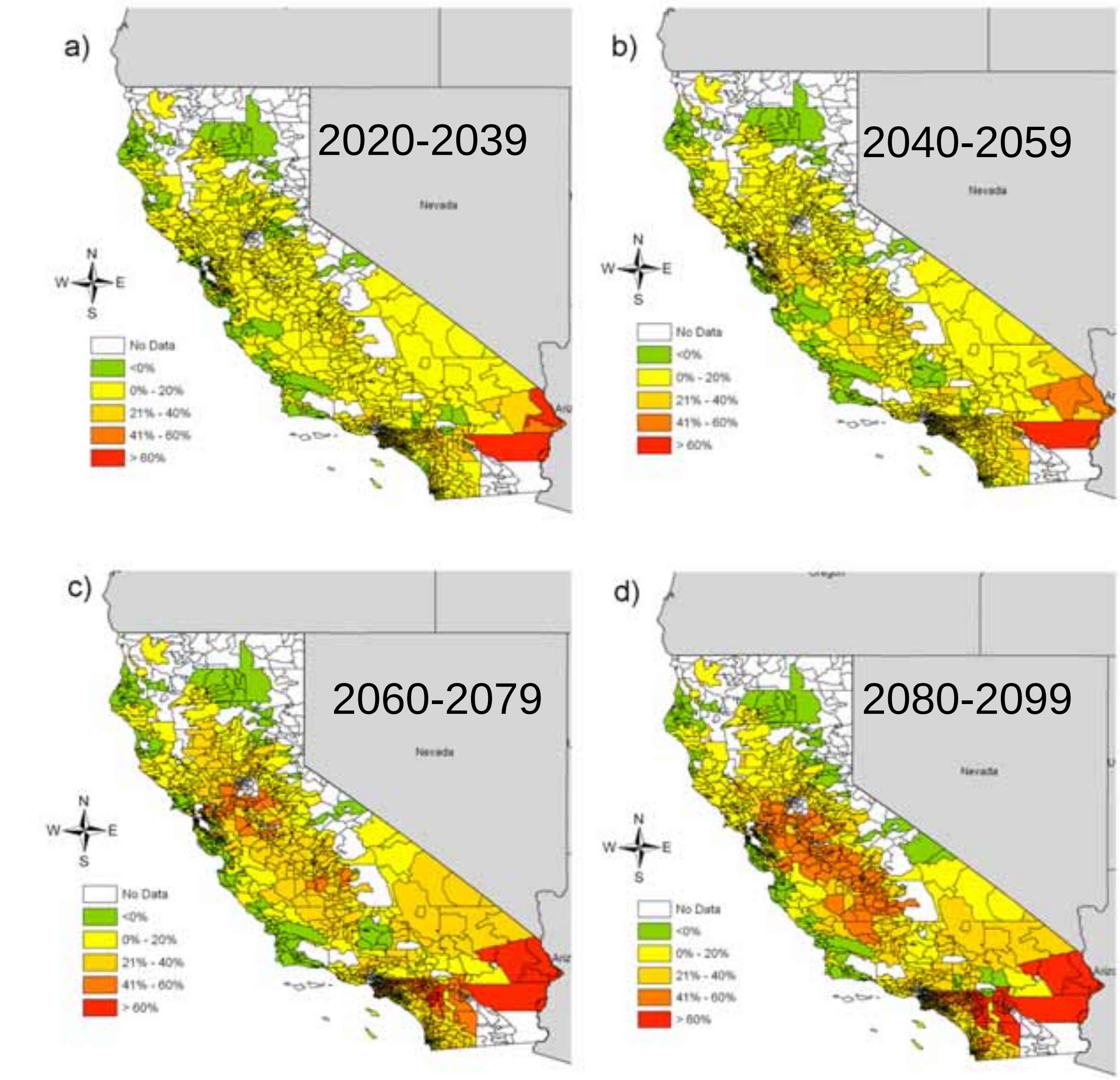
Change in number of days for 2080-2090 relative to 1980-1999
NCAR PCM model A2(black) B1(White)



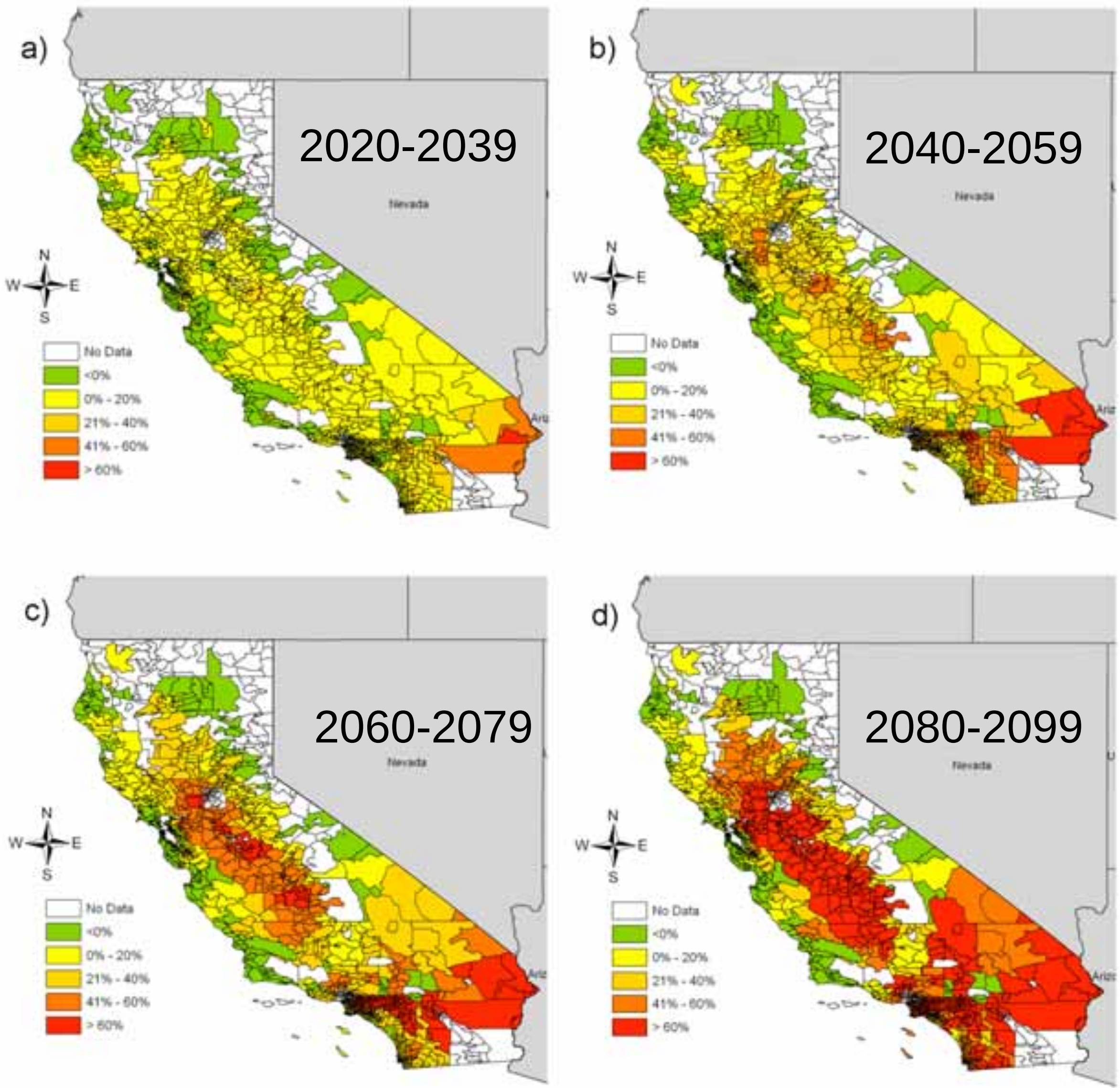
Baseline Simulation Assumption

- Temperature response function is fixed for each climate zone until the end of the century
  - In fact
    - households would adopt more cooling equipment if climate is warmer ➔ higher demand response in higher temperature bins
    - improvements in energy efficiency of appliances ➔ shift the temperature response curve downwards

Household Level Impacts (NCAR, B1)
(% over 1980-2000 simulated consumption)



Household Level Impacts (NCAR, A2)
(% over 1980-2000 simulated consumption)



Aggregate Demand Simulations

Temperature Increase Only Simulations

- calculate weighted average increase in household electricity consumption using the number of households by zip code as weights.

Bin Type		Equidistant				Percentile			
Downscaling		BCSD		CA		BCSD		CA	
IPCC Scenario		A2	B1	A2	B1	A2	B1	A2	B1
	Price Increase								
2000-19	±0%	5%	2%	5%	3%	6%	3%	5%	3%
2020-39	±0%	5%	8%	7%	8%	6%	9%	7%	8%
2040-59	±0%	15%	9%	17%	10%	17%	11%	17%	10%
2060-79	±0%	24%	15%	28%	16%	28%	17%	28%	16%
2080-99	±0%	48%	18%	50%	20%	55%	21%	50%	20%

Aggregate Demand Simulations
Temperature and Price Simulations

- Use estimated price elasticities of electricity demand for different income groups calculated by Reiss and White (2005).
- Assign price elasticity to each zip code based on the average household income for that zip code
- Four average household income buckets delineated by \$18,000 , \$37,000 and \$60,000
- Price elasticities are -0.49, -0.34, -0.37 and -0.29 respectively
- Two price scenarios
  - 30% increase in price starting in 2020
  - 30% increase in price starting in 2020 and 2040

Constant Price Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	5%	2%
2020-39	±0%	5%	8%
2040-59	±0%	15%	9%
2060-79	±0%	24%	15%
2080-99	±0%	48%	18%

30% Higher Price Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	5%	2%
2020-39	+30%	-6%	-3%
2040-59	+30%	3%	-2%
2060-79	+30%	11%	3%
2080-99	+30%	33%	6%

30%/30% Higher Price Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	5%	2%
2020-39	+30%	-6%	-3%
2040-59	+60%	-9%	-13%
2060-79	+60%	-1%	-9%
2080-99	+60%	18%	-6%

Aggregate Demand Simulations

Temperature and Population Simulations

- Using population projections data provided by The Public Policy Institute of California
- Projection at county level until 2100
- 3 scenarios
  - Low : 0.18% p.a.
  - Medium : 0.88% p.a.
  - High : 1.47% p.a.

Low Population Growth Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	17%	13%
2020-39	±0%	31%	34%
2040-59	±0%	48%	41%
2060-79	±0%	66%	52%
2080-99	±0%	113%	65%

Medium Population Growth Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	19%	15%
2020-39	±0%	48%	52%
2040-59	±0%	99%	88%
2060-79	±0%	154%	133%
2080-99	±0%	258%	179%

High Population Growth Scenario

Downscaling		BCSD	
IPCC Scenario		A2	B1
	Price Increase		
2000-19	±0%	23%	19%
2020-39	±0%	64%	68%
2040-59	±0%	135%	123%
2060-79	±0%	240%	212%
2080-99	±0%	464%	342%

Adaptation Demand Simulation
(% over 1980-1999 simulated consumption)

- Scenarios:
  - Zone 7: Entire state like San Diego
  - Zone 12: Entire state like Central Valley

(using percentile bins and BCSD downscaled)

	Zone 7		Zone 12	
Forcing	A2	B1	A2	B1
2000–19	1%	-1%	13%	7%
2020–39	1%	1%	5%	7%
2040–59	2%	1%	29%	13%
2060–79	2%	1%	57%	28%
2080–99	3%	0%	122%	40%

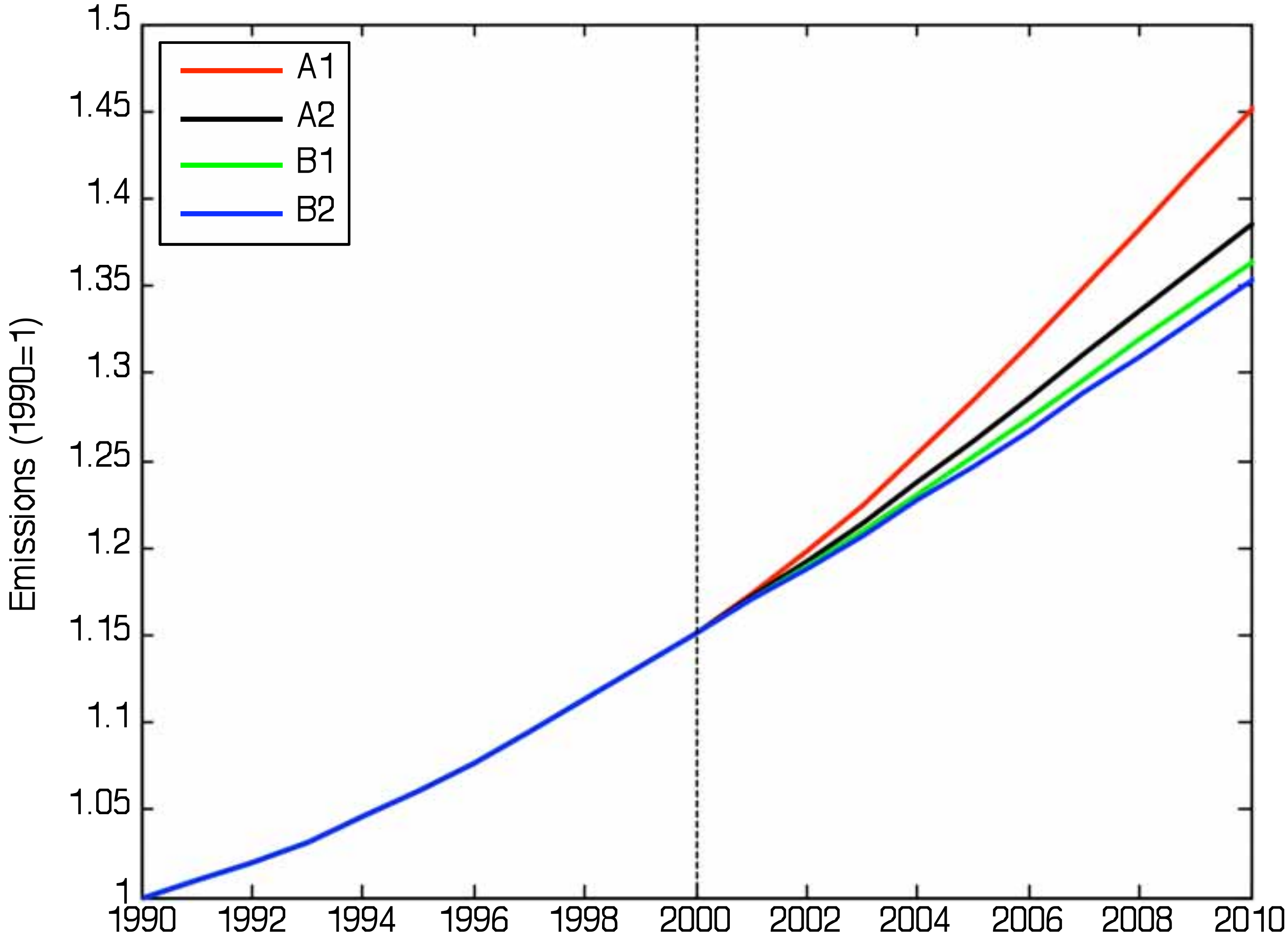
Temperature and Price Simulations
CARE vs Non-CARE

		NON-CARE		CARE		WEIGHTED	
Bin Type		Equidistant		Equidistant		Equidistant	
Downscaling		BCSD		BCSD		BCSD	
IPCC Scenario		A2	B1	A2	B1	A2	B1
	Price Increase						
2000-19	±0%	5%	2%	4%	2%	5%	2%
2020-39	±0%	5%	8%	4%	6%	5%	7%
2040-59	±0%	15%	9%	12%	8%	14%	9%
2060-79	±0%	24%	15%	20%	12%	23%	14%
2080-99	±0%	48%	18%	39%	15%	46%	17%
2000-19	±0%	5%	2%	4%	2%	5%	2%
2020-39	30%	-6%	-3%	-6%	-4%	-6%	-4%
2040-59	30%	3%	-2%	1%	-3%	2%	-2%
2060-79	30%	11%	3%	8%	1%	10%	2%
2080-99	30%	33%	6%	25%	3%	31%	5%
2000-19	±0%	5%	2%	4%	2%	5%	2%
2020-39	30%	-6%	-3%	-6%	-4%	-6%	-4%
2040-59	60%	-9%	-13%	-11%	-14%	-9%	-13%
2060-79	60%	-1%	-9%	-5%	-10%	-2%	-9%
2080-99	60%	18%	-6%	11%	-9%	16%	-7%

Summary

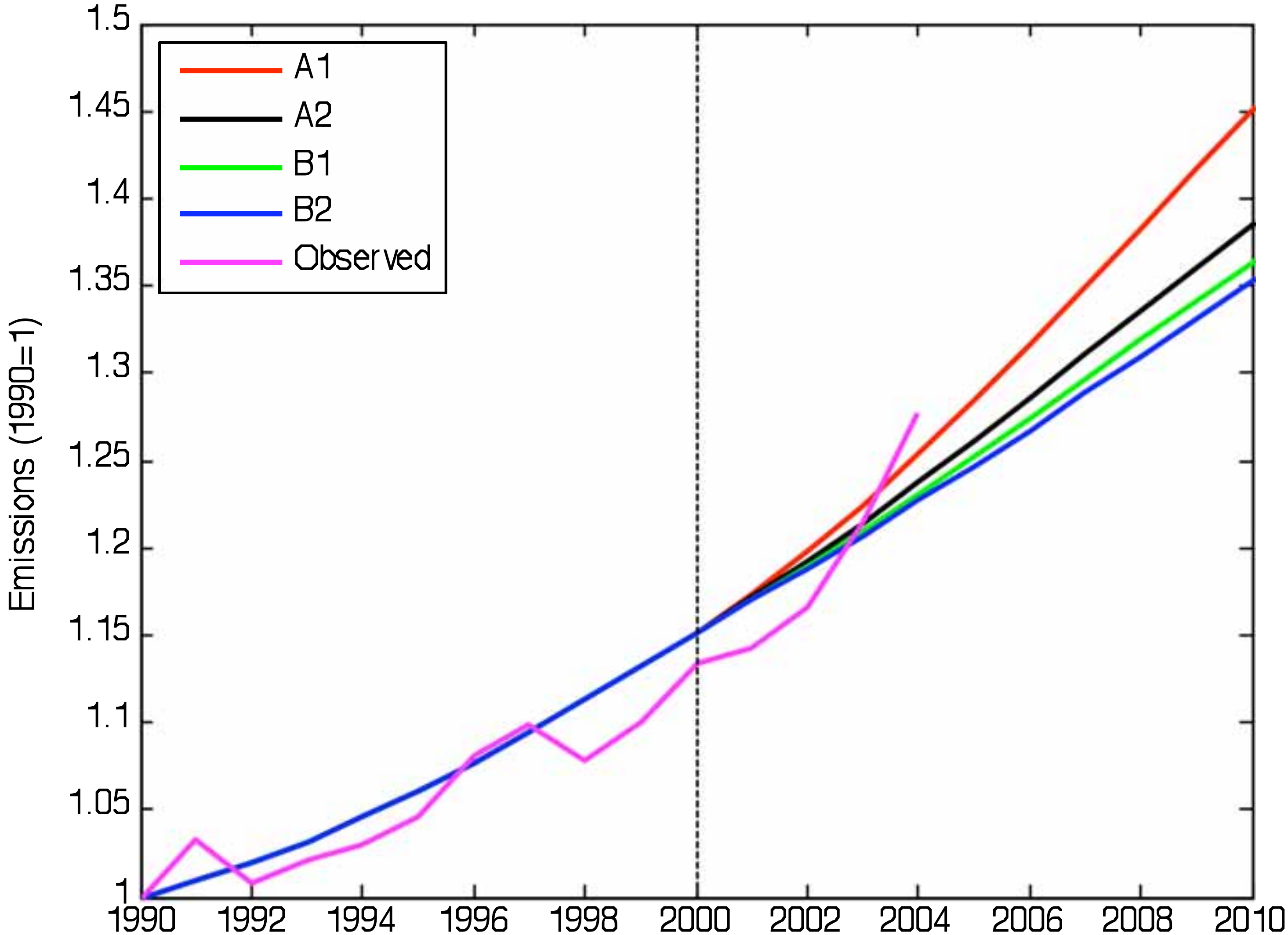
- California's residential electricity demand temperature response heterogeneous across climate zones.
- Study suggests larger increases in residential electricity demand than previous studies.
- Population uncertainty has a larger effect on overall demand than climate uncertainty
- Technology and price simulations suggest significant role for policy.

Official IPCC Emission Scenarios



Source: IPCC SRES (2000) – Fossil Fuel Related Carbon Emissions World

Actual emissions above worst case



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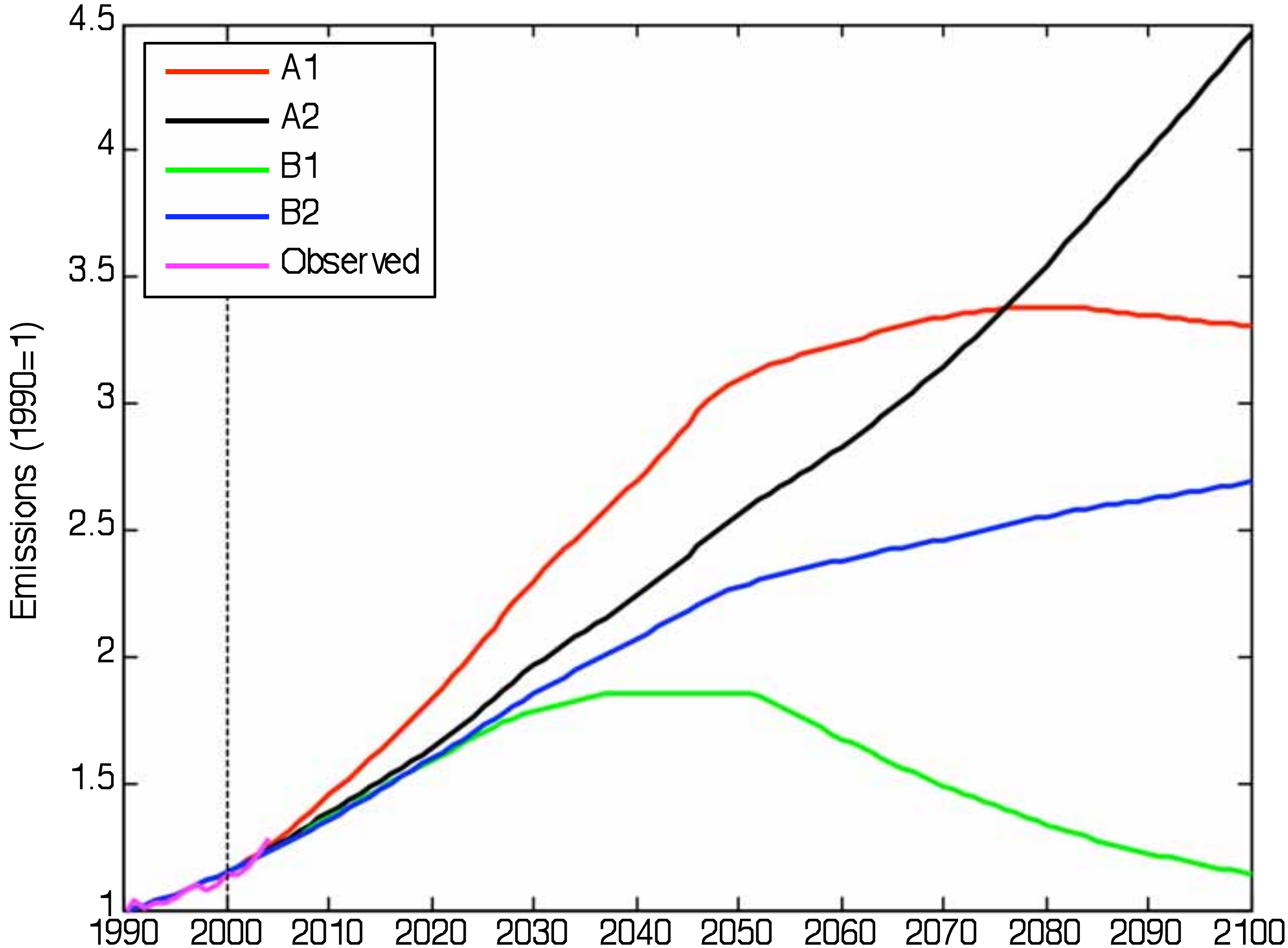
The IPCC long term trajectories



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